Evaluation of the Effects of Fortification of Refined Wheat Flour with Mango Peel, Pulp or Kernel Powders on the Quality Characteristics of Biscuit and Pan Bread

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ABSTRACT

Bakery products are the drivers of urban life; their consumption is high and widespread, more among the city dwellers. Fruits or vegetables residues regarded as waste are rich sources of dietary fibre, mineral and various bioactive compounds. Commercial refined wheat flour was partly replaced (15%) by mango pulp (Mpu), Peel (mpe) or kernel (Mk) powders on a weight basis, and thereafter the thoroughly mixed formulations were used to bake breads and biscuits using standard AACC (2000) procedures. The baked goods were evaluated for proximate, mineral and phytochemical compositions as well as sensory properties. The nutritive value of treated breads and biscuits samples were greatly enhanced, greater than observed in the controls. Moisture, protein, fat, ash, dietary fibre and carbohydrate of the breads were respectively 30.36-38.47%, 1.84-2.77%, 13.89-16.51%, 9.90-12.46, 1.84-2.77, 0.78-1.67%, 64.29-69.24 and 421.08-435.35 Kcal. As for the biscuits, mean values were 2.33-4.08% moisture, 22.55-25.06% protein, 12.74-16.03% fat, 1.50-2.19 ash, 1.34-1.85% crude fibre, 52.89-57.47% carbohydrate and 431.49-456 Kcal. Mineral elements (Na, K, Mg, Ca, Zn, Fe, Mn, Cu) we're higher in the mango pulp (WMpu) treated breads, followed closely by peel (WMpe) and seed flours (WMk) treated breads but as for the biscuits, WMk biscuits had greater mineral content than WMpe, WMpu and 100% wheat biscuits. The tannins, oxalates and phytates contents of the breads and biscuits were generally low but total flavonoids was greater in the mango peel and seed kernel treated samples than in the control. Although mango pulp enhanced the sensory attributes of the baked goods but those treated with mango peel or kernel powders had greater impact on the proximate, mineral and phytochemical contents of the breads and biscuits, yet wheat bread had greater specific volume although specific volumes were generally low (1.85-2.35 ml/g), lower in the treated breads and but the heavier WMpu breads with compact crumb had the highest absolute volume. Spread ratios (8.6-9.39) of biscuits were greater in mango powder treated biscuits. Although WMk bread had the best mouthfeel yet the crumb and crust colour were the poorest. WMpe bread had the poorest mouthfeel and taste, and wheat bread the best texture, but other attributes were not significantly different from MWpu bread, which had the best colour, taste and acceptability. WMpu biscuits were rated higher in terms of color/appearance, texture, taste and overall acceptability while crispiness score of wheat biscuit was not significantly different from WMpe biscuits. The bottomline is the acceptance score of mango pulp breads and biscuits were higher and their physicochemical and sensory properties competed favourably with those of wheat bread and biscuit. Therefore, commercial production of mango peel, pulp, and kernel powders is advocated for baked goods fortification.

Keywords: Mango peel; Pulp; Kernel powders; Food fortification; Phytonutrients; Composite bread; Composite biscuits.

▦ 1.0. Introduction

Wheat is the world foremost grain in terms of volume of food products obtainable for human utilization, international grain trade, food availability and security. Wheat cultivation and processing helped nurture past and current civilizations (Dewettinck et al., 2008), and its role in this direction has not abated, instead increasing urbanization continue to spike its consumption in form of breads, biscuits, pastries, couscous, various thin and thick porridges among others. Bread, a spongy yeasted confection is the commonest wheat based baked good in Nigeria while biscuit, a crispy low moisture flat cake obtained from chemically leavened soft wheat dough is an ever-present snack, the foremost snack in urban centers globally. Adoption of modern lifestyles and the associated consumption of refined cereals have paved the way for unceasing violence of diseases, hitherto uncommon. This calls for food fortification through incorporation of edible plant residues known for high content of health promoting bioactive compounds. This becomes imperative considering the fact that both breads and biscuits are produced and consumed on wider scale from refined flours, which are obtained through repeated grinding and sifting in the milling process for the retrieval of the starchy endosperm. This process has led to loss of beneficial micro and macro nutrients and non-nutrient phytochemicals (Awika, 2001; Prasad, 2009), which are needed for nutrition and well-being of humans. Fortification of refined wheat flour with synthetic chemicals has not stopped

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the onslaught of noncommunicable diseases prevalent in the world currently, although lifestyle changes such as inactivity, consumption of processed ready-to-eat, ready-to-cook foods or so-called convenient foods may partly contributed to this menace.

Biscuits in generally contain disproportionately high amounts of fats, refined sugar and low amounts of dietary fibre, and because biscuits are attractively flavored, therefore the tendency to over-consume is high leading to pervasive malnutrition endemic in resource poor families especially among the school age youths who are the main consumers of refined and low fibre cereal-based products. Unlike the developed economies, bread consumption on in developing countries like Nigerian is unrelenting, and predisposing factors may not be restricted to insecure farmlands, population surge, climate change and currently, Covid-19 pandemic, yet these factors more than any other have elicited food insecurity through decreased food accessibility, availability and affordability. Consequently, there is increased dependence on refined cereals in form of ready-to-eat processed foods such as breads, biscuits, noodles, couscous etc., which are obtained from refined wheat flours which have been depleted of non-nutrient phytochemicals, the latter are plant based bioactive compounds ignorantly labelled antinutrients but with the advancement of science, these chemicals are now proved to be health promoting factors when their daily consumption do not exceed the healthful thresholds.

Phytochemicals such as phenolics are known antioxidants which are able to obliterate oxidative stress, and in tissues scavenge free radicals that pose deleterious effects on cell membrane integrity and therefore exacerbate the risk factors that promote many chronic diseases (Liu, 2004). Epidemiological and animal-based studies suggest that regular consumption of fruits and vegetables and whole grains reduces the risk of various diseases linked with oxidative damage (Boeing et al., 2012; Liu, 2004). Incorporating powdered plant residues hitherto discarded as waste that liter the environment has generated a lot interest to food scientists because the so-called wastes are rich sources of bioactive compounds such as polyphenols, flavonoids, isoflavones, antocyanidins, phytoestrogens, terpenoids, carotenoids, limonoids, phytoesterols, glycosinolates and fibres, etc.

Biscuits and Bread which are consumed on large scale can be used as a vehicle for food fortification, to deliver much needed micronutrients and phytochemicals to the populations at the fringe micronutrient deficiency through incorporation of fruit or vegetable residue powders such as mango pulp, kernel or peel or from other tropical fruits which are abundant in Nigeria, although seasonal. Fruits generally are known to be loaded with dietary fibres, minerals, vitamins and other phytochemicals. Mango fruit (*Mangifera indica*) is a drupe of the anarcadiaceae family, consisting three distinct parts: the outer skin, inner flesh surrounding a centrally placed seed, each part is differently constituted chemically. This fruit vary in size, shape and flesh color and sweetness. The seed on average is about 17-22g of the fruit (Song and Barlow, 2006), with proximate composition comparable to those of the most cereals with respect to carbohydrate (69.22-79.78), protein (5.6-9.5%), fats (8.35-16.13%), fibre (0.4-2.45%), ash (0.35-3.66%) (Dhingra and Kapoor, 1985).

Mango fruit has considerable value as source of pigments, dietary fibre and antioxidants (Rocha et al., 2007) such as the carotenes and lutein. In several studies, mango peel was incorporated in some food products such as muffin (Ramires Maganda et al., 2015); cookies (Bandyopadhyay et al., 2014); macaroni (Ajila et al., 2010) as well as used for fermented mango peel wine (Vara Kumar et al., 2014). The present study had investigated the effects of

fortification of wheat flour with mango pulp, peel and kernel powders on the quality characteristics of wheat biscuit and bread.

1.1. Objectives of the study

The main objective of the study was to incorporate powders from mango peel, pulp, and kernel into refined wheat flour and thereafter evaluate the effects on the physicochemical and sensory properties of biscuits and pan bread. The specific objectives were to: i) procure matured partially ripe mangoes and transformed the peel, pulp and kernel into powders; ii) prepare product formulations by incorporating separately mango powders into refined wheat flour; iii) bake breads and biscuits using the formulations; iv) evaluate the physical, chemical and sensory properties of the breads and biscuits; and v) determine the phytochemical contents of the breads and biscuits.

2.0. Materials and Methods

2.1. Source of materials and equipment

The raw materials used for this study were obtained from Maiduguri Monday market and mangoes from Abuja Sheraton mango garden, Maiduguri. Other materials included wheat flour, salt, and sugar (Dangote, Nigeria limited), salt (Dangote, Nigeria Ltd), dried yeast (Sonai, Nigeria PLC), margarine (Double King, Nigeria PLC.). All equipment used in the processing of bread and biscuit were obtained from the Department of Food Science and Technology Food LAB, University of Maiduguri and chemical analysis were carried out at the Chemistry Department, Yobe State University, Damaturu, Nigeria.
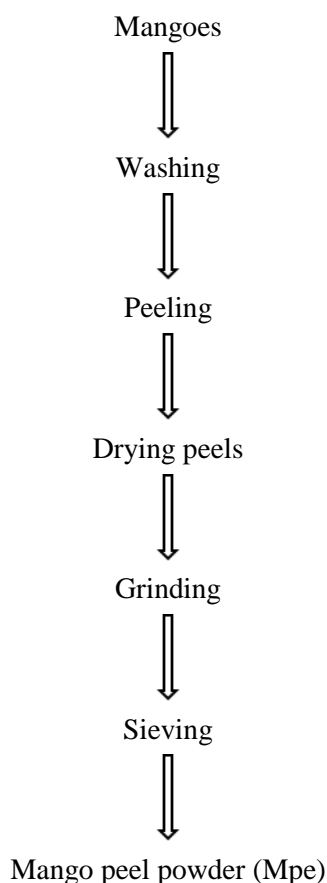
Mangoes

↓

Washing

↓

Peeling

↓

Drying peels

↓

Grinding

↓

Sieving

↓

Mango peel powder (Mpe)

Figure 1. Flow Chat for Mango Peel Flour Preparation

2.1.1. Preparation of mango peel flour (Mpe)

The mangoes were washed in clean running water to remove dirt and unwanted materials. After that, a sharp stainless knife was used to peel off the peels in thin slices around the flesh, the slices were dried in a cabinet dryer at 60 °C for 12 h and later ground into powder using an electric blender, the powder was passed through 0.25 mm sieve mesh (Figure 1).

2.1.2. Preparation of mango pulp powder (Mpu)

After the peels were removed, the flesh was neatly sliced off and cut into tiny irregular slices and sprayed on aluminum trays with adequate spacing to allow faster drying, dried in a cabinet dryer at 60 °C, 16 h and later ground, sieved using 0.25 mm mesh (Figure 2).

2.1.3. Preparation of mango kernel flour (Mk)

After the pulp was sliced off, the nuts were cut into tiny pieces after removing the outer coat of the kernels and the pieces of the kernels were soaked overnight in water and later boiled in 2% sodium metabisulpite for 10 min (Bede et al., 2010) and dried in a cabinet dryer at 60°C, 12h and ground into powder, sieved with 0.25mm mesh (Figure 3).

Mango

⇓

Washing

⇓

Peeling

⇓

Slicing pulp

⇓

Drying pulp slices

⇓

Grinding

⇓

Sieving

⇓

Mango pulp powder (Mpu)
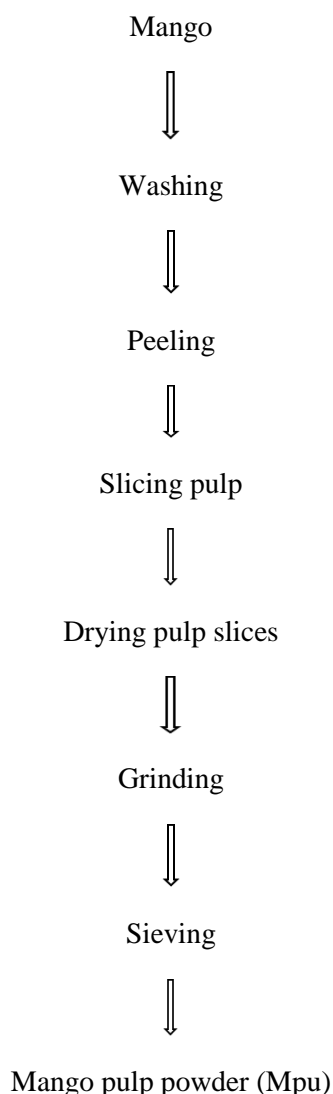
Figure 2. Flow chart for mango pulp powder preparation (Mpu)

Mangoes

⇓

Deseeding

⇓

Removal of seed coats

⇓

Dicing

⇓

Boiling (2% sodium metabisulphite)

⇓

Drying

⇓

Grinding

⇓

Sieving

⇓

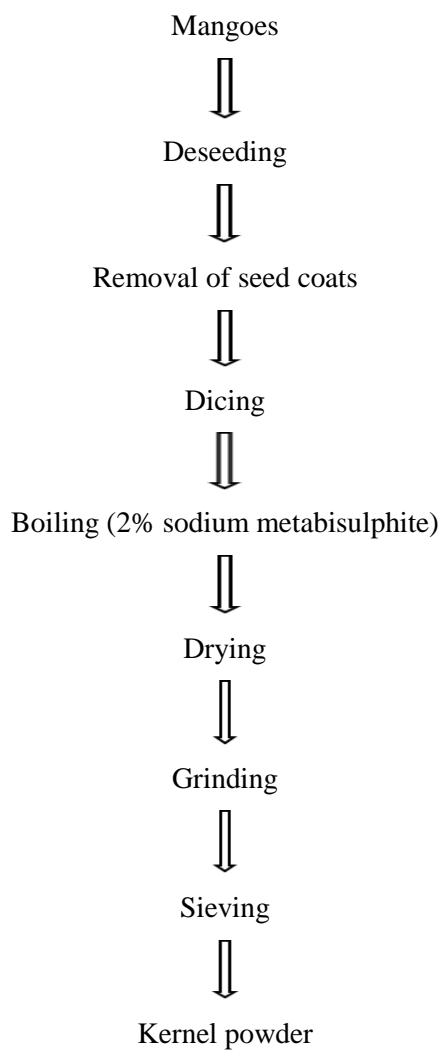Kernel powder

Figure 3. Flow chart for mango kernel powder preparation (Mk)

Plate 1. Dried mango pulp slices

Plate 2. Dried mango peel slices

Plate 3. Dried mango kernel slices

2.1.4. Blend formulations for bread and biscuit preparation

(i) W (100:00): Wheat flour;

(ii) WMpe (85:15): 85%Wheat flour (W), 15% mango peel powder (Mpe);

(iii) WMpu (85:15): 85% Wheat flour, 15% mango pulp powder (Mpu);

(iv) WMk (85:15): 85% wheat flour, 15% mango kernel powder (Mk).

Table 1. Recipe for pan bread preparation

Ingredient	Weight (g)	Percent (%)
Wheat Flour (W)	800	100
Granulated Sugar	40	5
Iodized Salt	8	1.0
Dried Yeast	12	1.5
Shortening	48	6.0
(W: Mpe) 85:15	680:120	68:12
(W: Mpu) 85:15	680:120	68:12
(W: Mk) 85:15	680:120	68:12
(Water) Ml	480-560	60-70

SOURCE: AAOC 2000

2.2. Bread Making

Breads were prepared using the straight dough method of AOAC method (2010). However, dried ingredients: wheat flour, sugar, flour/flour blend, salt, yeast were uniformly mixed in a kitchen mixer to ensure uniformity, after which water was added and mixed, finally fat was mixed in manually on a greased board. The dough mass was rounded and placed in the fermentation cabinet for the first fermentation time of 90 minutes. After, the dough was degassed and portioned into dough pieces (300-350g), molded into cylindrical shapes and placed in greased pans and allowed to proof for 60 min, after the panned dough was placed into hot oven and baked at 220 ^{0}C for 30 min (Figure 4). The various breads were allowed to cool to room temperature, weighed and the volumes measured using fonio seeds displacement method a modification of method described by Giami et al. (2004) and the specific volumes of the breads were calculated.

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Wheat flour

⇓

Addition of ingredients

⇓

Mixing

⇓

First fermentation

⇓

Degassing

⇓

Kneading
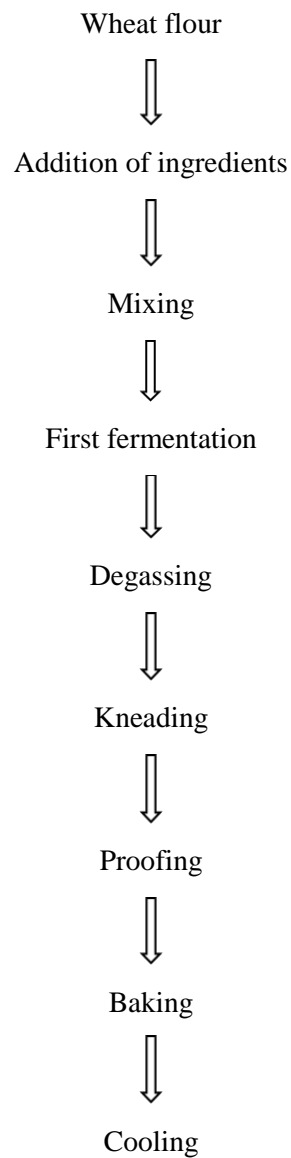
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Proofing

⇓

Baking

⇓

Cooling

Figure 4. Flow chart for bread preparation

Plate 4. Wheat bread (100: 00)

Plate 5. Mango kernel bread (85:15)

Plate 6. Mango pulp bread (85:15)

Plate 7. Mango peel bread (85:15)

Table 2. Recipe of biscuit production

Ingredient	Quantity(g)	%
Wheat flour (W)	300	100
Margarine	90	30
Granulated Sugar	90	30
Baking powder	4.5	1.5
Egg	3	1
W:Mpe (85:15)	255:45	85:15
W:Mk (85:15)	255:5	85:15
W:Mp (85:15)	255:45	85:15
Milk powder	15	5

2.3. Biscuit preparation

Biscuit was prepared using the traditional creaming method. The fat and sugar were mixed in a Kenwood mixer (HM 430) until mixture was fluffy. Egg and milk were added, while mixing continued, then baking powder, flour and salt were introduced into the mixture to form soft dough. The dough was removed from the bowl and kneaded on a flat surface to obtain a uniform mix. The kneaded dough was rolled out into sheet using a rolling pin and cut into the desired shape using a cutter internal diameter of 6.5cm. The cut pieces were transferred to the greased baking tray. Baking was carried out at 180^0C for 15 minutes in a gas oven.

Sugar

⇓

Margarine

⇓

Kneading

⇓

Addition of egg

⇓

Kneading

⇓

Baking powder

⇓

Mixing

⇓

Addition of composite flour

⇓

Kneading

⇓

Rolling

⇓

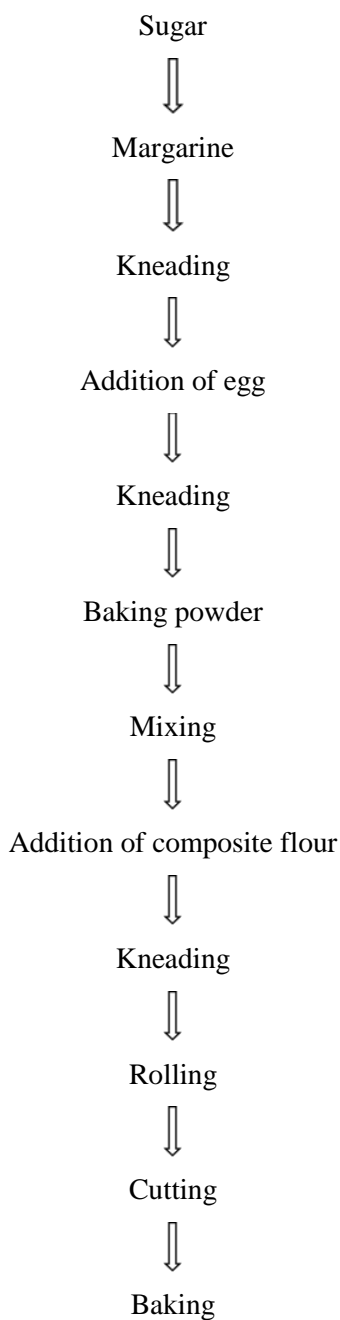Cutting

⇓

Baking

Figure 5. Flow chart for preparation of biscuits

Plate 8. Mango pulp Biscuit (85:15)

Plate 9. Mango peel Biscuit (85:15)

2.4. Proximate composition analysis

Proximate compositions of the baked products were analyzed according to established procedures of the AACC (2000). Moisture (oven drying at 105 °C 1h), crude fat (extraction in a soxhlet apparatus using petroleum ether), crude protein (%Nx6.25, using microKjedahl method), crude fiber (alternate hydrolysis with dilute acid and with dilute alkali before incineration at 500-600 °C, 4-5 h, total ash (weight difference before after incineration in a muffle furnace, 500-600 °C, 5 h respectively, according to AACC (2000) methods: 925.09, 4.5.01, 979.09, 962.09 and 923.03 Carbohydrate contents were calculated by 'difference'.

2.5. Physical Properties of bread and biscuit

Plate 10. Mango kernel Biscuit (85:15)   **Plate 11.** Wheat biscuit (100:00)

2.5.1. Diameter of biscuit

The diameter and thickness of three randomly selected biscuits was measured using a digital vernier caliper. Average values were reported in centimeter.

2.5.2. Weight of Bread and Biscuit

Weight of bread and biscuits were measured as average values of three individual weighing with the help of an analytical weighing balance. Average values for weight were reported in grams.

2.5.3. Thickness of biscuit

The diameter (D) of the biscuits was also determined by measuring the length of six well-formed biscuits placed horizontally edge to edge and dividing by six, again the same biscuits were stacked vertically to obtain the height, dividing by six to obtain the average thickness (T) of the biscuits, with D and T, the spread ratios (D/T) and the spread factors were calculated. (AACC, 2000)

$$\text{Spread Factor} = \frac{spread\ ratio}{spread\ ratio\ of\ control} x100 \qquad (1)$$

2.5.4. Bread volume

Bread volume was determined by modification (Giami et al., 2004) of the rapeseed displacement method of AACC (2000) using Fonio seeds instead of rapeseeds, specific volumes (bread volume divided by the bread weight) were obtained.

2.6. Mineral contents of samples

Two grams of each dried samples were dry-ashed and the ash mixed with 10ml 20% HCl in a volumetric flask, heated on a water bath, cooled and filtered, the filterate made up to 100ml in an Erlenmeyer flask. Concentrations of the Ca, Mg, Fe, Zn, Cu, Mn in the aliquot samples of the filtrate were obtained using atomic absorption spectrophotometer (Model 3100, Perkin-Elmer, USA) while those of Na and K were assayed using flame photometer (Model PF P7 Jenway, UK) and P was determined colorimetrically using Vanado-molybdate method of AOAC (1990) was used to determine P concentration. Concentrations of the minerals (mg/100g) were obtained from respective standard calibration curves constructed using standard solutions of the respective minerals.

2.7. Phytochemical Contents of the samples

2.7.1. The Phytate Contents of Samples

The method described by Abou–Arab and Abu-Saleem (2009) was adopted for phytate determination. Four grams (4g) of sample was dissolved in 100 ml of 2% HCl, left to stand for 5h, 25 ml of filtrate was mixed with 5 ml of 0.3% ammonium thiocyanate solution.

The resulting mixture was titrated with iron (iii) chloride solution until a brown-yellow end-point persisted for 5 min. Phytate concentrations were extrapolated from a standard curve made with serial dilution of standard phytic acid solution.

2.7.2. Tannin content of the samples

The Folin-Denis spectrophotometric method as described by Pearson (1976) was used to determine the tannins content of the samples. One gram of the sample was dispersed in 10 ml distilled water and agitated. This was left to stand for 30 minutes at room temperature and shaken every 5 minutes. After this, it was centrifuged at 3000 rpm for 5 mins to obtain the extract, thereafter 2.5 ml of each extract and 2.5 ml of standard tannic acid solution were dispersed into separate 5 ml flasks and 0.1 ml Folin-Denis reagent was measured into the separate flasks, followed by addition of 2.5 ml of saturated Na_2CO_3 solution.

The mixture was diluted and incubated for 90 min at room temperature. The absorbance was measured at 700 nm. The reading was taken with the reagent blank at zero, and tannin contents extrapolated from the calibration curve made using a serial dilution of standard tannic acid and results expressed as tannin acid equivalent per g of sample.

2.7.3. Determination of oxalic acid contents of the samples

The oxalic contents of the various samples were determined using the titration method described by Mishra et al. (2017). Each sample (1.0g) was extracted with dilute H_2SO4, the mixture was boiled in a water bath for 30 min, thereafter 10ml of the filtrate was diluted to 50 ml with dilute H_2SO4 and titrated to a permanent pink endpoint with 0.003M $KMnO_4$ solution.

Using the molar ratio $M_1V_1=M_2V_2$ where M_1 & V_1 are the molarity of $KMnO_4$ and the titre value respectively, M_2 & V_2 are the molarity of the oxalate ion and the original volume of the extract respectively. The concentration of oxalate ion (g/L) was the product of its molarity and molar mass and transformed to mg oxalate per g sample.

2.7.4. Determination of total flavonoids of the samples

Extracts from the samples were prepared according to Phuyal et al. (2020) and total flavonoid contents (TFC) in methanolic extracts of dried samples were determined using aluminum chloride colorimetric assay. The calibration curve was prepared using serially diluted standard solution of quercetin, absorbance for the test and standards were measured at 510nm against a reagent blank. TFC were expressed as milligram quercetin equivalent per g sample (dwb).

2.8. Sensory evaluation of the samples

The sensory attributes (crust & crumb appearance, mouthfeel, taste, texture, sponginess and acceptability) of breads and the attributes (colour, taste, texture, crispiness, and acceptability) of the various biscuits were evaluated by the twenty (20) selected staff and students of the Faculty on the basis of 9-point Hedonic scale during two different sessions in well lit Lab for organoleptic tests.

2.9. Statistical Analysis

The data generated were statistically analyzed using standard procedure for completely randomized design. Data were subjected to analysis of variance (ANOVA) critical difference were accepted at a p-value of 5% ($p<0.05$). The new Duncan's multiple range test was utilized to separate the means. Results were reported as mean ¥SE. A Statistical Package for Social Sciences (SPSS) version 16 was the software that enabled statistical analysis of generated data.

▓ 3.0. Results and Discussion

3.1. Proximate composition of the various breads made from blends of wheat flour supplemented with either mango kernel, mango peel or mango flesh

Wheat-mango kernel (WMpe) bread had the highest moisture (38.47% as-is basis) significantly different from the moisture content of wheat bread (30.36%) the least, wheat-mango kernel (WMk) bread (32.39%) and wheat-mango pulp (WMpu) bread (33.38%), which might be due to higher fiber content of the WMpe bread (1.67%) significantly not different from crude fiber content of WMk (1.61%) but different from 1.40% of wheat-mango pulp powder (WMpu) bread and 0.78% in wheat bread. Significant difference was not found between the moisture content of WMpu (33.38%) and WMk (32.36%) breads (Table 3.1). Pathak et al. (2017) reported linear increase in bread moisture with increase in mango peel addition. Baking conditions, ingredient type and bread formulation are the main determinants of the moisture content of oven fresh bread, but in this case fibre content is the determining factor because fibrous materials are known to possess higher water holding capacity. Lakshmi et al. (2014) reported a comparable moisture range of 29.26-39.39% for multigrain bread containing mango kernel flour among others. Ash contents of the breads varied from the highest in WMpu (2.77%) to the lowest value of 1.84% in wheat bread, the ash contents of WMk and WMpe were respectively 2.15% and 2.39%. Pinto et al. (2017) reported higher ash and fibre contents in composite bread treated with vegetable powders. Protein (13.89-16.51%) and fat (9.90-12.46%) contents of the treated breads were slightly enhanced, greater enhancements were recorded for breads containing mango kernel firstly and bread with mango peel powder secondly. The fat contents of the various breads ranged from 9.94% (wheat bread) to 12.46% (WMk). The same trend was observed in the protein contents

of the various breads, WMk bread had the highest and the wheat bread the least. Protein content reported by Lakshmi et al. (2014) was greater for multi grain bread with added mango kernel powder. Wheat bread contain the least dietary fiber (0.78%) while the mango peel bread had the highest (1.67%), followed by mango kernel bread (1.61%), the values obtained here were lower than dietary fiber of 1.9-2.4% reported by Lakshmi et al. (2014) either due to lower blending ratio (85:15) with respect to mango powders in the formulation or their processing regimen. Rocha et al. (2017) and Ajila et al. (2008) reported mango peel as a rich source of dietary fiber. Bandyopadhyay et al. (2014) reported higher ash and fibre in mango peel and higher fat and protein in mango kernel powders. Carbohydrate (NFE) content determined by 'difference' reflected the amounts of other nutrients especially protein, fat and moisture and varied from the least value in WMk (64.29%) to the highest value of 69.24% in wheat bread. Zambelli et al. (2017) equally reported an appreciable increase in protein, fat, and ash contents of vegetable powder treated bread than the untreated wheat bread. The calorific values followed the same trend reflecting the higher oil and protein contents of mango kernel treated bread and ranged from 421.08 kcal in WMpu to 435.34 kcal in WMk but significant difference was not observed in the calorific values of WMpu, WMpe and wheat breads.

Table 3.1. Proximate composition (%dwb) of the various breads made from blends of wheat flour with either mango kernel or mango peel or mango flesh powders

Formulation	Moisture (as-is)	Moisture (Dwb)	Ash	Lipid	Protein	Fibre	NFE	Energy (Kcal)
WMk (85:15)	32.36± 0.0[b]	3.36± 0.08[bc]	2..15± 0.03[c]	12.46± 0.06a	16.51± 0.04a	1.61± 0.01a	64.29± 0.06d	435.34±0.72a
WMpe (85:15)	38.47± 0.0[a]	3.47± 0.08[b]	2.39± 0.04a	10.31± 0.08[b]	15.41± 0.04ab	1.67± 0.01[a]	66.80± 0.09[c]	421.63±0.76[b]
WMpu (85:15)	33.38± 0.1[b]	4.38± 0.10[a]	2.77± 0.04[a]	10.96± 0.07bc	14.49± 0.05[ab]	1.40± 0.01[c]	66.10± 0.07b	421.08±0.89b
W (100:00)	30.36± 0.0c	4.36± 0.09[a]	1.84± 0.02[d]	9.90± 0.16c	13.89± 0.10b	0.78± 0.00[d]	69.24± 0.16[a]	421.62±1.24[b]

Values are mean ±SE (n=3). Mean values bearing different superscripts are significantly different (0<0.05). W: wheat flour, Mk: mango kernel, Mpe: mango peel, Mpu: mango pulp powders.

3.2. Proximate composition of the various biscuits made from blends of wheat flour supplemented with mango kernel, mango peel, mango flesh

Significant variations existed in the proximate compositions of the various biscuits Table 3.2. Mango powders treated biscuits had greater nutrient enhancement than the untreated wheat biscuit. The moisture contents of the various biscuits were generally low, a range of 2.33% (WMpu) and 4.08% (WMk) and were significantly different (p<0.05). The roundish flat pieces of dough of low thickness got thoroughly dehydrated within 15 min exposure to oven temperature during baking. Higher dietary fibre in WMpe biscuit led to significant higher moisture numerically but others had moisture contents that were not significantly different. Biscuits are generally low moisture foods which translates to high storage stability and crispness. The ash content of wheat-mango peel (WMpe) biscuits were significantly higher (2.19%), higher than 1.93% recorded for WMk and 1.75% for WMpu biscuit and wheat biscuits had the least ash (1.50%). Wheat-mango kernel (WMk) biscuits had the highest fat

content (16.03%) and WMpe biscuits the least (12.74%) lower than in the wheat biscuits (14.51%) and 14.43% in WMpu. The protein contents (22.55-25.06%) of the biscuits were unexpectedly high, perhaps due to low moisture contents of the biscuits which enhanced their dry matter contents, wheat biscuit had the least, and biscuits containing the mango kernel the highest significantly not different from the protein contents of WMpe biscuits (24.43%). Combined effects of wheat and mango fruit proteins (although of little amount) might be responsible or higher presence of non-protein nitrogen. The dietary fiber contents of the various biscuits varied from the least in WMpu biscuits (1.34%) to 1.85% in WMpe biscuits the mean values obtained for WMk (1.54%) and wheat biscuit (1.55%) were not significantly different ($p>0.05$). Carbohydrate (NFE) contents varied from 52.89% (WMk) to 57.47% (W 100:00) the highest but not significantly different from 57.42% recorded for WMpu biscuits. The calorific values (431.49-456.07 kcal) of the various biscuits were higher in WMk and W biscuits and the least was obtained in peel containing biscuits which had the least fat content. There were enhancement of the nutrient profile of the treated biscuits in this study, greater than the control and comparable with the proximate composition of several commercial biscuits studied by Hossain et al. (2013). Fakhreddin Saleh (2020) noted that mango powder could enrich biscuits with fibre, minerals, carotenoids and polyphenols.

Table 3.2. Proximate composition of the various biscuits made from blends of wheat flour supplemented with either mango kernel or mango peel or mango flesh

Formulation	Moisture	Ash	Lipid	Protein	Fibre	CHO	Energy (Kcal)
WMk (85:15)	2.56± 0.06[b]	1.93± 0.03[b]	16.03± 0.05[a]	25.06± 0.02[a]	1.54± 0.00[b]	52.89± 0.08[c]	456.07± 0.56[a]
WMpe (85:15)	4.08± 0.08[a]	2.19± 0.03[a]	12.74± 0.05[c]	24.43± 0.03a[b]	1.85± 0.01[a]	54.78± 0.01[b]	431.49± 0.65[c]
WMpu (85:15)	2.47± 0.05b[c]	1.50± 0.02[c]	14.43± 0.03[b]	22.55± 0.09[b]	1.34± 0.01[c]	57.47± 0.08[a]	449.91± 0.39[b]
W (100:00)	2.33± 0.06c	1.75± 0.03[b]	14.51± 0.05[a]	22.69± 0.02[b]	1.55± 0.00[b]	57.42± 0.08[a]	451.01± 0.49[b]

Values are mean ±SE (n=3). Mean values bearing different superscripts are significantly different (0<0.05). W: wheat flour, Mk: mango kernel, Mpe: mango peel, Mpu: mango pulp powders.

3.3. Mineral compositions of the various breads made from blends of wheat flour fortified with either mango kernel or mango peel or mango pulp powder

There were significant differences in the mineral contents of the various breads (Table 3.3). Sodium (Na), potassium (K), magnesium (Mg), phosphorus (P), zinc (Zn), iron (Fe), manganese (Mn) and copper (Cu) contents of the various breads varied significantly ($p<0.05$) and the range of concentrations observed were, 60.00-77.74, 46.15-59.20, 70.71-93.51, 59.11-76.21, 0.64-1.20, 1.16-2.16, 0.07-0.14 and 0.08-0.10 respectively. The elements were consistently higher in the breads containing mango pulp powder (WMpu), perhaps the pulpy environment favours high solubility for the elements, also of note was higher amounts of microelements in the WMk and WMpe breads than in wheat breads. Dominant elements in mango seed according to Fowomola (2010) are Ca and Mg. Odunlade et al. (2017) similarly reported improved mineral contents (Mg, Fe, Na, Zn, Ca) of breads treated with

vegetable powders than wheat bread, but higher concentrations were reported which linearly increased with increase in vegetable powders inclusion.

Table 3.3. Mineral composition (mg/100g) of the various breads made from blends of wheat flour supplemented with either mango kernel or mango peel or mango flesh

Parameters	Sodium	Potassium	Magnesium	Phosphorous	Zinc	Iron	Manganese	Copper
WMk (85:15)	60.00 ± 1.17^b	46.15 ± 0.76^c	71.70 ± 1.55^b	64.91 ± 0.13^c	0.92 ± 0.01^c	1.66 ± 0.00^c	0.12 ± 0.02^a	0.09 ± 0.01^c
WMpe (85:15)	62.23 ± 1.21^b	47.99 ± 0.79^c	74.08 ± 1.60^b	68.86 ± 0.13^b	0.95 ± 0.01^b	1.70 ± 0.00^b	0.13 ± 0.02^a	0.06 ± 0.01^d
WMpu (80:15)	77.74 ± 1.53^a	59.20 ± 0.99^a	76.21 ± 0.16^a	76.21 ± 0.16^a	1.20 ± 0.00^a	2.16 ± 0.00^a	0.14 ± 0.00^a	0.10 ± 0.01^a
W (100:00)	75.54 ± 1.49^a	56.33 ± 0.96^b	59.11 ± 0.38^d	59.11 ± 0.38^d	0.64 ± 0.01^d	1.16 ± 0.01^d	0.07 ± 0.02^e	0.08 ± 0.01^b

Values are mean ±SE (n=3). Mean values bearing different superscripts are significantly different (0<0.05). W: wheat flour, Mk: mango kernel, Mpe: mango peel, Mpu: mango pulp powders.

3.4. Mineral compositions of the various biscuits made from blends of wheat flour supplemented with mango kernel or mango peel or mango pulp

Significant variations ($p<0.05$) existed in the mineral contents of the various biscuits as presented in Table 3.4. Unlike observation in mineral contents of bread, in this case, WMk and WMpe biscuits contained higher levels, and least amounts were in wheat biscuits. The variations obtained in the study were, Na: 61.27-86.93, K 70.44-109.17, Mg 111.87-192.89, P 96.27-107.19, Zn 1.70-2.16, Fe 3.07-3.88, Mn 0.20-0.27 and Cu 0.12-0.18 and the order of dominance of the elements in the various biscuits was Mg<P<K<Na<Fe<Zn<Mn<Cu. Macro-elements (Na, K, Me, P) were observed to be higher in peel containing biscuits while micro-elements (Zn, Fe, Mn, Cu) higher in mango kernel biscuits. Kaur and Brar (2017) similarly reported higher amounts of mineral elements in biscuits treated with mango kernel flour, with significant higher Ca, Fe, and Na.

Table 3.4. The mineral composition of the various biscuits produced from blends of wheat flour fortified with either mango kernel or mango peel or mango pulp powder

Formulation	Sodium	Potassium	Magnesium	Phosphorous	Zinc	Iron	Manganese	Copper
WMK(85:15)	67.32 ± 1.34^b	77.35 ± 1.32^b	122.66 ± 2.06^b	107.19 ± 0.08^a	2.16 ± 0.00^a	3.89 ± 0.01^a	0.27 ± 0.01^a	0.17 ± 0.01^a
Wmpe (85:15)	86.93 ± 1.79^a	109.17 ± 2.08^a	192.89 ± 4.16^a	105.90 ± 0.11^b	2.00 ± 0.00^a	3.60 ± 0.01^b	0.24 ± 0.01^b	0.17 ± 0.01^a
Wmpu (85:15)	64.65 ± 1.29^c	73.68 ± 1.28^c	118.52 ± 2.56^c	96.27 ± 0.07^c	1.92 ± 0.00^b	3.45 ± 0.01^b	0.22 ± 0.02^{bc}	0.18 ± 0.00^a
W (100:00)	61.27 ± 1.21^d	70.44 ± 1.21^d	111.87 ± 2.42^d	$97.71\pm0.05c$	1.71 ± 0.01^c	3.07 ± 0.00^c	0.20 ± 0.01^c	0.12 ± 0.02^b

Values are mean ±SE (n=3). Mean values bearing different superscripts are significantly different (0<0.05). W: wheat flour, Mk: mango kernel, Mpe: mango peel, Mpu: mango pulp powders.

3.5. Phytochemical compositions (mg/g) of the various breads made from blends of wheat flour with either mango kernel, mango peel or mango pulp powder

Tannin, flavonoid, and phytate contents of the various breads were generally low either due to low level of mango powders used in the formulations or due to deleterious effect of oven temperature (Peprah et al., 2018) or due to processing method or conditions (Table 3.5). Pallermo et al. (2014) noted that changes in phytchemical contents of cooked vegetables might result from either thermal degradation or softening of the food matrix. The values obtained varied from 0.05-0.07mgTE/100g, 0.87-1.13 mg/100g and 0.06-0.09mgQE/100g tannins, total flavonoids, and phytates respectively. Oxalate concentrations were not even lower, phytate contents of the breads were not significantly different and low, the total flavonoids in WMpe (1.13 mg/g) and WMk (1.12 mg/g) breads

were equivalent and higher than observed in wheat bread (0.87 mg/g) and WMk bread (0.89 mg/g). Peprah et al. (2018) reported total phenolics content of bread treated with Borassius aethiopicum fruit pulp was lower than observed in wheat bread. Calcium oxalate is partly responsible for kidney stone and sources are said to be both exogenous and endogenous. Okombo and Liebman (2010) reported far higher total oxalates of 16.5-45.9mg/100g and 23.7-389mg/100g in samples of bread and crackers respectively. Flavonoids are generally antioxidants, they help regulate cellular activities and neutralize free radicals that cause oxidative stress and diseases. Yatna et al. (2014) reported substantial decrease in the tannin contents of mango kernel flours subjected to processing treatments of soaking or autoclaving or both. Tannins are the most abundant antioxidant in human diets and has beneficial health properties when available in moderate amounts (Hans et al., 2007). Equally, oxalates, phytates and tannins can adversely affect nutrient bioavailability in human nutrition when their safe threshold levels are exceeded.

Table 3.5. Phytochemical compositions (mg/g) of the various breads made from blends of mango kernel or mango peel mango powder

Formulation	Tannins	Flavonoids	Oxalates	Phytates
WMk (85:15)	0.05 ± 0.02^a	1.12 ± 0.02^a	0.01	0.09 ± 0.01^a
WMpe (85:5)	0.05 ± 0.01^a	1.13 ± 0.02^b	0.01	0.09 ± 0.02^b
WMpu (85:15)	0.07 ± 0.00^a	0.89 ± 0.03^b	0.01	0.08 ± 0.01^b
W (100:00)	0.06 ± 0.02^a	0.87 ± 0.02^a	0.02	0.06 ± 0.01^c

Values are mean $\pm$SE (n=3). Mean values bearing different superscripts are significantly different (0<0.05). W: wheat flour, Mk: mango kernel, Mpe: mango peel, Mpu: mango pulp powders.

3.6. Phytochemical compositions of the various biscuits produced from blends of wheat flour with either mango kernel or mango peel or mango pulp powder.

Here also, as in the case of breads, the phytochemical contents of the various biscuits were low yet not lower than the levels of tannins and phytates in plantain-wheat-melon seed cookies reported by Oludumila and Adetimehin (2016) or in wheat-cassava-carrot biscuits studied by Adelakun and Gbadebo (2019). Oxalate, phytates, and tannins concentrations were low (Table 3.6) due to processing conditions. This collaborates with the findings by Fowomola (2010) of low level of antinutrients in mango seed. Oxalates are known to be affected by processing conditions. Weiwen Chai et al. (2005) reported 30-87% loss of soluble oxalates, more during boiling than steaming and baking. As for total flavonoids, a subgroup of phytochemicals, WMpe biscuits had significant greater amount (1.04mgQE/100g) while the levels in WMpu, WMk, and W biscuits were lower and no significant difference was noticed among them. Fruit peels including mango peels are good sources of phytochemicls as observed by Ajila et al. (2008) in mango peel treated biscuits, reported to contain higher level of phenolics with higher scavenging activity. Pawde et al. (2020) fortified biscuits with dragon fruit powder and at 50% replacement of wheat flour the highest, total phenolics of 0.0092 mg% (gallic acid equivalent) was reported, an insignificant increase. In another study, an increase in total phenolics and total flavonoid contents were reported by Mahloko et al. (2019) for wheat biscuits fortified with either 4% banana or 4% prickly pear peel powders. Similarly, Al-Saab and Gadallah (2021) observed the same scenario in orange peel powder (0-20%) treated biscuits. Although phytates cause micronutrients deficiency because of metallic ions chelating ability, however according to Kumar et al. (2021), it

possesses antioxidant, antidiabetic, and antibacterial activities, therefore there is no need to panick for the presence of the so-called antinutrents except when their safe threshold values are exceeded.

Table 3.6. phytochemical compositions (mg/g) of the various biscuits made from blends of wheat flour fortified with either mango kernel or mango peel or mango pulp powder

Formulation	Tannins	Flavonoids	Oxalates	Phytates
WMk(85:15)	0.05±0.00a	0.67±0.02b	0.01	0.14±0.01a
WMpe (85:15)	0.08±0.02a	1.04±0.02a	0.01	0.06±0.01b
WMpu(85:15)	0.05±0.01a	0.65±0.02b	0.01	0.13±0.01a
W (100:00)	0.05±0.01a	0.61±0.02b	0.04	0.13±0.01a

Values are mean ±SE (n=3). Mean values bearing different superscripts are significantly different (0<0.05). W: wheat flour, Mk: mango kernel, Mpe: mango peel, Mpu: mango pulp powders, ND: not detectible.

3.7. Physical properties of the various breads made from blends of wheat flour supplemented with mango kernel or mango peel or mango pulp powder

The weight of the loaves ranged from 282.82g to 333.20g, wheat bread had the least weight significantly ($p<0.05$) not different from WMpe bread, and WMpu bread was the heaviest (Table 3.7). The addition of non-wheat flour encouraged higher water absorption therefore higher weight of the treated breads and consequent volume depressing effect of gluten dilution. The subsequent reduction in steam and carbon dioxide retention capacity in composite flour dough caused a decline in loaf volume (615-665 ml). The higher volume and smaller weight of the untreated wheat bread led to higher loaf specific volume (2.35 ml/g) which decreased in the treated breads (2.35-1.85 ml/g), although absolute volume of pulp treated bread was higher. Presence of natural sugars in the mango pulp powder in addition to added sugar in the formulation might be responsible for higher weight due to higher water retaining capacity which led to lowest specific volume for WMpu bread (1.85), therefore higher bread density with less visible air pockets due to compacted crumb structure but with less fixtures or cracks on the bread crust. Although, the loaf specific volumes (LSV) of the breads were low, however the values were within the range (2.10-2.69ml/g) reported by Pathak et al. (2017) for mango peel (1-5% inclusion) treated breads but lower than LSV of 3.6-4.3ml/g reported by Odunlade et al. (2017) for breads fortified with different levels of vegetable powders, even smaller levels of the powders were used in that formulations.

Table 3.7. Physical properties of the various breads made from blends of wheat flour supplemented with either mango kernel or mango peel or mango powder

Formulation	Weight (g)	Volume (cm^3)	Specific volume (cm^3/g)
WMk (85:15)	312.57±6.39[b]	631.67±7.64[b]	2.02±0.17[c]
WMpe (85:15)	297.1±13.34[c]	633.33±71.82[b]	2.13±0..03[b]
WMpu (85:15)	333.20±9.82[a]	615.00±36.06[c]	1.85±0.06[d]
W (100:00)	282.83±13.69[d]	665.00±13.23[a]	2.35±0.14[a]

Values are mean ±SE (n=3). Mean values bearing different superscripts are significantly different (0<0.05). W: wheat flour, Mk: mango kernel, Mpe: mango peel, Mpu: mango pulp powders.

3.8. Physical properties of the various biscuits made from blends of wheat flour fortified with either mango kernel or mango peel or mango powder

Table 3.8 represents the physical properties of various biscuits, the weights, diameters, thickness, spread ratios and spread factors differed significantly (p<0.05). The biscuit weights ranged from 35.27g to 57.60g, WMpe biscuit had the least while WMpu biscuit had significant higher weight than others perhaps due to higher sugar or soluble matter content of the added mango pulp powder, which perhaps held more water firmly than mango peel and kernel powders and resisted thorough dehydration at oven temperature although fibre rich WMpe biscuit had higher moisture for obvious reasons. There was no significant or systematic variation in biscuit diameters (6.29-6.50 cm), but as for the biscuit thickness (0.67-0.73 cm), no significant difference was observed but the spread ratio increased linearly from 8.67 for wheat biscuit to 9.39 in WMk biscuit. Roggers (1994) and Miller et al. (1997) posited that cookie spread rate is a function of dough viscosity which in turn is a function of flour composition primarily gluten proteins content, therefore addition of non-wheat flour leads to low dough viscosity or reduced binding capacity, which in turn leads to higher flow rate (spread) and therefore larger cookie diameter and lower thickness. Emire and Legesse (2012) reported an increase in biscuit width and thickness with increase in mango kernel powder addition. Contrarily, Al-Saab and Gadallah (2021) reported a decrease in diameter and an increase in thickness and spread ratio with increasing addition of orange peel powder. It implies that spread ratio correlates positively with nutritive value or it is an index of biscuit nutrient density or an indication of biscuits produced from composite flours.

Table 3.8. Physical properties of the various biscuits made from blends of wheat flour supplemented with either mango kernel or mango peel or mango powder

Parameter	Weight (g)	Diameter (cm)	Thickness (cm)	Spread Ratio	Spread Factor (%)
W (100.00)	46.13±0.31b	6.33±0.24b	0.73±0.12a	8.67±0.77d	100
WMk (85:15)	35.27±0.76c	6.29±0.21b	0.67±0.06a	9.39±.75a	108.31
WMpe (85:15)	44.23±0.82b	6.50±0.10a	0.70±0.10a	9.29±0.58b	107.15
WMpu (85:15)	57.60±0.72a	6.40±0.26a	0.71±0.15a	9.01±0.68c	103.92

Values are mean ±SE (n=3). Mean values bearing different superscripts are significantly different (0<0.05). W: wheat flour, Mk: mango kernel, Mpe: mango peel, Mpu: mango pulp powder.

3.9. Sensory evaluations of the various breads made from blends of wheat flour fortified with mango kernel or mango peel or mango pulp powder

Significant variations (p<0.05) existed in the sensory attributes of the various breads Table 3.9. Numerically, WMpe (peel treated bread) had more even porosity, other attributes were poorer and with the least acceptability score, however it was not rejected by the panelists. Wheat bread had the best crumb appearance, texture, and its score was significantly similar to peel bread which had the highest porosity score. Pulp treated bread had the best taste, poorest porosity perhaps due to higher soluble solids content, and had highest acceptability score, while bread containing mango kernel powder had the best mouthfeel, its texture was significantly not greater than that of the control. WMpu competed favorably with wheat bread for the attributes evaluated, because their scores in most cases were higher but not significantly different. With similar fermentation and baking conditions, the only operating variable was the mango powders, mango pulp (WMpu) treated bread outscored mango kernel (WMk) bread and WMk did better than mango peel bread (WMpe), darker brown appearance of WMk notwithstanding.

Higher fat content of mango seed kernel impacted better mouthfeel than observed in the control, and mouthfeel relates to impressions from tactile perceptors of mucous membranes of the bucal cavity which indicates the juicyness, oilyness, viscousness, dryness, etc., of saliva infused bulous. Cracks or fissure lines were more on peel and kernel containing breads, both being more fibrous than wheat flour bread which affected their appearance scores in addition to poorer bread symmetry, which is an outcome of gluten dilution, this effect was pronounced more in kernel and peel powders treated breads than mango pulp or wheat bread. Crust appearance/colour is a function of the extent of Maillard browning reaction and bread shape which received poor rating from the test panelists.

Table 3.9. Sensory evaluations of the various breads made from blends of wheat flour supplemented with either mango kernel or mango peel or mango powder

Formulations	Crust Appearance	Crumb Appearance	Mouth feel	Taste	Texture	Porosity	Acceptability
WMk (85:15)	6.80	6.20	8.20	7.60	8.40	7.00	7.00
	$\pm1.48^c$	$\pm1.78^c$	$\pm0.53^a$	$\pm0.45^a$	$\pm0.51^a$	$\pm1.14^b$	$\pm0.89^b$
WMpe (85:15)	6.60	6.00	6.80	5.80	6.20	8.00	6.60
	$\pm0.89^c$	$\pm1.35^c$	$\pm0.84^c$	$\pm1.34^b$	$\pm0.45^b$	$\pm1.23^a$	$\pm1.34^c$
WMpu (81.15)	7.40	6.60	7.10	7.80	7.40	6.80	8.00
	$\pm1.67^b$	$\pm1.32^b$	$\pm0.84^b$	$\pm1.34^a$	$\pm1.52^b$	$\pm1.64^b$	$\pm0.71^a$
W (100:00)	8.20	7.40	7.40	7.70	8.20	7.80	7.20
	$\pm0.84^a$	$\pm1.37^a$	$\pm0.77^b$	$\pm1.30^a$	$\pm0.60^a$	$\pm0.84^{ab}$	$\pm1.92^b$

Values are mean $\pm$SE (n=3). Mean values bearing different superscripts are significantly different (0<0.05). W: wheat flour, Mk: mango kernel, Mpe: mango peel, Mpu: mango pulp powders.

3.10. Sensory evaluations of the various biscuits made from blends of wheat flour supplemented with either mango kernel or mango peel or mango pulp powder

On a 9-point Hedonic scale, WMpu biscuits had better taste but not significantly different from the control, this is because of the higher sweetness of mango pulp powder added, WMpe and WMk biscuits had equivalent lower taste scores because higher contents phytochemicals, which are known for strong taste notes and colour. Texture (defined here as degree of softness) of mango peel biscuits was poorly rated apparently because of higher fibre content which led to higher hardness score than others but WMpu biscuits had significant better texture greater than the 100% wheat biscuit (control) while the texture of the control and mango kernel treated biscuits were not significantly different. Biscuits texture is a function of quality and quantity of shortening, sugar, wheat flour strength, leavening agent, and presence of non-wheat flours or their particle size. Wheat biscuits had higher crispiness (defined here as flaky dried, soft-hard) and the scores varied from 6.33 to 7.87, next was the peel biscuits (WMpe), while kernel powder biscuits had the least crispness score perhaps due to greater oil content or finer texture of mango seed flour. As for colour attributes of the biscuits, WMpu scored the highest (8.20), kernel and peel biscuits the least, kernel powder is naturally brown and that of peel developed during drying due to enzymatic browning, both further darkened during baking process, however the colour scores were higher in WMk than in WMpe biscuits. WMpu received the highest acceptability score (8.13), and WMpe biscuits the least while the

control and WMk had equivalent acceptability scores (Table 3.10). Dad et al. (2019) observed darkness of the crust and crumb of wheat-mango kernel treated cake. Bandyopadhyay et al. (2014) equally observed that more than 20% mango kernel or peel powder inclusion affected negatively cookies sensory attributes however Ashoush and Gadallah (2011) reported that 40% mango kernel powder addition to wheat flour yielded acceptable biscuits. Al-Saab and Gadallah (2021) reported that more than 5% orange peel powder caused deterioration of cookies sensory attributes

Table 3.10. Sensory evaluations of the various biscuits made from blends of wheat flour fortified with either mango kernel or mango peel or mango powder

Formulation	Taste	Texture	Crispy	Colour	Acceptability
WMk (85:15)	6.74 ± 1.44^b	7.00 ± 2.12^b	6.33 ± 1.84^d	7.47 ± 1.98^{bc}	7.53 ± 1.32^{bc}
WMpe (85:1)	6.73 ± 1.03^b	6.07 ± 1.58^c	7.13 ± 1.77^b	7.00 ± 1.36^c	7.20 ± 1.36^c
WMpu (85:15	7.33 ± 1.88^a	7.52 ± 1.87^a	6.93 ± 1.28^c	8.20 ± 1.20^a	8.13 ± 1.25^a
W (100:00)	7.09 ± 1.84^{ab}	7.07 ± 1.39^b	7.87 ± 1.64^a	7.92 ± 1.60^b	7.73 ± 1.79^b

Values are mean ±SE (n=3). Mean values bearing different superscripts are significantly different (0<0.05). W: wheat flour, Mk: mango kernel, Mpe: mango peel, Mpu: mango pulp powders.

4.0. Conclusion

Apart from poorer sensory attributes of mango peel and kernel treated breads and biscuits, however they had superior nutrient density and contained more non-nutrient phytochemicals than wheat bread or biscuit. Reduced bread specific volume is a problem common with application of composite flour in bread making. Higher acceptance scores of mango pulp bread and biscuits and in cases better physicochemical properties underscores the importance of fruit powders in food fortification and their commercialization advocated. From the foregoing the following recommendations become imperative: the need to commercialize fruit powders production for better availability and affordability, and considering the fact that the majority of these fruits are seasonal; the resurgence in New age diseases calls for increase production and consumption of functional foods through enrichment of refined cereals.

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